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Review

New services and roles of biodiversity in modern agroecosystems: A review

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A R T I C L E I N F O

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A B S T R A C T

Ecosystem services and biodiversity are critical to ensure sustainable development of agricultural activities. Based on available scientific knowledge, high shares of biodiversity are followed by more carbon sequestration, reduced soil erosion risk, improved production and food security. This review aims to detect biodiversity services in three aspects; (1) providing ecosystem services in modern agroecosystems in response to future challenges, (2) the ability of biodiversity to support agroecosystems, and (3) the agenda for future research on biodiversity. To address our research objectives, we conducted a widespread literature search to estimate new services and roles of biodiversity in modern agroecosystems. The search was set from the date of the first relevant article until the end of the year 2017. Biodiversity is measured by many indices. Many recent studies have proposed new methods and software for biodiversity assessment such as BioFTF, BAT, LaDy and Entropart. According to the present literature review, biodiversity has a pervasive role in climate change adaptation and mitigation strategies. Levels of biodiversity, such as genetic, species and ecosystem, can affect pest control in several ways such as biological control, resulting in complex multi-trophic interactions. The relationships between land use and biodiversity are fundamental in understanding the links between people and their environment. Two models have been planned to increase production in agroecosystems whilst minimizing the consequences for biodiversity: land sharing and land sparing. Studies have shown how biodiversity can be integrated into Life Cycle Assessment (LCA) on a global scale. LCA mainly introduces biodiversity as an endpoint category modeled as a loss in species richness due to the conversion and management of land in time and space. This review shows that ecological restoration of agroecosystems is generally effective and can be recommended as a way to increase biodiversity in agricultural ecosystems. The conservation, management, and sustainable use of these services require specific attention and a coherent global policy approach. In conclusion, to protect biodiversity in agroecosystems, a policy consonance and strategic support to ecosystems should be considered. This review suggests that advanced research are needed on relationships between biodiversity and genetic erosion, map of life, pest control and urban agriculture.

1. Introduction

Biodiversity is a vital property of ecological systems. It is generally explained as a variety of all forms of life in terrestrial, marine, and other aquatic ecosystems (Overmarset al., 2014). Thus, investigations should incorporate different levels of biodiversity at genetic, species, or ecosystem level. This depends on principal observation objectives, ecosystem characteristics and general richness of elements in the ecosystem (Moonen and Bàrberi, 2008). Each species, living within an ecosystem, introduces processes and creates flows of energy, substances, and materials. Therefore, the disappearance of a single species can lead to irreversible changes and consequently change ecosystem properties towards undesired directions (Dirzo and Raven, 2003). Life diversity stabilizes the ecological function and allows biogeochemical systems (e.g. water cycle, flow of greenhouse gases, and carbon sequestration), to work in a balanced manner. At the same time, biodiversity is directly linked to food production, provision of substances for medicines, and delivery of energy sources. Moreover, some species play a fundamental role within the spiritual, cultural, and/or religious ceremonies. As a result, biodiversity is an irreplaceable good for society (Dirzo and Raven, 2003; Henzen, 2008; UNEP, 1999).

This review aims to detect biodiversity services in agroecosystems and consider the potential benefits of biodiversity for improved agroecosystems functioning in the following three aspects:

1) the ability of biodiversity to support ecosystems as modern

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Table 1
State of the art biodiversity including its services and roles.

State of the art biodiversity in …	Description	Service	References
Sustainable agriculture	Sustainable agriculture seeks to support farmers' resources and communities by promoting farming practices and methods that are profitable, environmental friendly, and beneficial for communities.	provisioning, supporting, cultural, supporting	OECD (2001), Schmidt and Wei (2006)
Agrobiodiversity	Agrobiodiversity refers to the biodiversity of agroecosystems along with species of crops and farm animals, the genetic variance within populations, and respective varieties and races.	provisioning, supporting, cultural, supporting	Baudron and Giller (2014), Yao and Li (2010)
Urban agricultural (UA)	Production of crop and livestock products within cities and towns is referred to as urban agriculture (UA).	provisioning, supporting, cultural, regulating	Zezza and Tasciotti (2010), McLain et al. (2012), Lin et al. (2015)
Pest control	Cultural, mechanical, chemical, and biological controls are the most applied options to overcome diseases and pest.	regulating, supporting	Benbrook (2001), Philpott (2013)
Food security and health	Food security is generally referred to the availability and accessibility of food for human. The World Bank defines food security as the access of food to all people for an active and healthy life at all times.	provisioning, supporting	World Bank (1986), Maxwell and Wiebe (1999)
Carbon sequestration	Carbon sequestration is the process involved in carbon capture and the long-term storage of atmospheric carbon dioxide.	provisioning, regulating, supporting	Hajjar et al. (2008), Batjes and Sombroek (1997)

agroecosystems, urban agriculture, and sustainable agriculture ecosystem;

2) the role of biodiversity in providing ecosystem services such as food security, pest control, and ecological restoration, and its effect on climate change, land uses, genetic erosion, and carbon sequestration;
3) the agenda for future research on biodiversity.

As a 10,000-year-old treasure in agricultural activities, biodiversity is the basis and foundation of ecosystem services, essentials to sustain agriculture and human well-being. Thousands of years of human intervention have led to the current crop and livestock biodiversity. Biodiversity and agriculture are strongly interrelated. While biodiversity is critical for agriculture, sustainable use of biodiversity corresponds to agricultural structure and function, and thus is an indicator for farming practices. Indeed, biodiversity is considered as a vital component of sustainable agriculture from food security, nutrition, and livelihoods viewpoints (Schmidt and Wei, 2006). In addition, biodiversity can be used in order to gain a better understanding of dynamics and resilience of shifting (slash and burn) cultivation systems (Blanco et al., 2013).

Higher carbon sequestration, lower erosion risk and higher production are the most important results of high biodiversity stocks (Bullocket al., 2007; Overmarset al., 2014). The biodiversity in agroecosystems can be categorized as either planned or unplanned diversity. Planned diversity includes the spatial and temporal arrangement of domestic plants and animals that farmers purposely include in their farming system, e.g. bio-control agents or plant-related nitrogen-fixing bacteria (Altieri, 1999; Power, 2013). Unplanned diversity (or associated diversity) includes other associated remaining organisms after transition of a system to agriculture from the surrounding landscape. A variety of weeds, herbivores, predators, parasites, and microorganisms are predominantly found in any ecosystem, even a simplified one such as an agroecosystems (Power, 2013).

Recent studies revealed a global decline in biodiversity (Shoyama and Yamagata 2014; Baudron and Giller, 2014). Threats and pressures on biodiversity increased, during the last decade (Shoyama and Yamagata, 2014). Cropland area in the developed world decreased about 50% between 1961 and 1999 (Wik et al 2008; Baudron and Giller, 2014). Globally, the total area of cropland increased by more than 20% in the developing world and this trend is expected to continue until 2050 (Green et al., 2005; Balmford et al., 2005; Gibbs et al., 2010; Baudron and Giller, 2014). The most biodiversity–rich areas on the earth are located in developing countries. Given the current level of information gained on the role of biodiversity, it is more crucial than ever to reduce the contemporary level of resource degradations. Therefore, increasing agricultural production in the developing world and minimizing adverse effects on biodiversity abundance should be considered a priority for environment conservation (Baudron and Giller, 2014). McCauley (2006), Putz and Redford (2009), and Rands et al. (2010) have expressed concerns that emphasizing on ecosystem services might be at the expense of biodiversity conservation, whereas others have suggested that markets for ecosystem services would provide funding for conservation activities.

To plan a strategy protecting current biodiversity levels, understanding the present biodiversity conditions are required. The consequences and potential countermeasures from land management and climate change on biodiversity need to be analyzed and the regions with priority action should be defined (Booth, 2012).

2. Methods

To address our research objectives, we conducted a widespread literature search to estimate new services and roles of biodiversity in modern agroecosystems. To refine the pool of searched literature that met our criteria, Scopus and Web of Science as two the world's largest citation databases were used. Some papers were identified by investigative the bibliographies in the review papers and papers that cite these. The search was set from the date of the first relevant article until the end of the year 2017. The following keywords were used at each query: 1) agrobiodiversity, 2) sustainable agriculture, 3) urban agricultural, 4) pest control, 5) life cycle assessment, 6) carbon sequestration, 7) ecological restoration, 8) land-use influencing biodiversity, 9) effects of climate change on biodiversity, 10) food security, 11) genetic erosion, and 12) biodiversity measurement methods. The outcome of this review is presented in Results and Discussion sections.

3. Results

3.1. State of the art biodiversity in agricultural systems

Many key ecosystem services and roles are provided by biodiversity. They are shown in Tables 1 and 2. To understand of the art and role biodiversity in agriculture, it is necessary to study the status of biodiversity services in agriculture systems or agrobiodiversity. Biodiversity is one of the basic principles sustainable agriculture, food security and health and it is one of the most important elements to manage the systems toward a sustainable agroecosystems. Biodiversity provides different services in new agricultural systems such as urban agriculture. Today, the most important challenges of modern agriculture include pest control, CO_2 emissions, and genetic erosion. All practices that increase diversity in agroecosystems and various time scales can improve

Table 2
Services of biodiversity to ecosystem.

Relationship of biodiversity with …	Description	Service	References
Life Cycle Assessment (LCA)	LCA is a systematical method to assess environmental impacts of products and/or services. It considers all inputs and outputs involved from the generation to the waste of a product and/or service in respect to the environment.	regulating, supporting	Baan et al. (2013), Souza et al. (2015)
Ecological restoration (ER)	Ecological restoration is considered a major strategy to improve the provision of ecosystem services and reversing biodiversity losses.	regulating, supporting	Bullock et al. (2011)
Land use	Land use involves the management and modification of natural environment into built environment such as settlements, arable fields, pastures, and managed woods.	regulating, supporting, cultural	Haines-Young (2009), Henzen (2008), Michelsen (2008)
Climate change	Climate change is a change in the statistical distribution of weather patterns when that change lasts for an extended period of time.	regulating, supporting	Sahney et al. (2010)
Genetic erosion	The loss of genetic diversity is known as genetic erosion, which is commonly referred to as the reduction in the quantities of specimens of a species.	regulating, supporting	Wolff (2004)

agroecosystems capability to pest control and sequester carbon. Ecological restoration of agroecosystems could be advised as an effective way to improve biodiversity in these ecosystems. In contrast, most land cover/land use changes can effect biodiversity and reduce related ecosystem services. Also, the biodiversity could be integrated into LCA at global scale, with regard to species richness of a natural reference situation compared to different land use types. Based on available scientific knowledge, these services and challenges were reviewed in this section.

3.1.1. Agrobiodiversity

The term 'agrobiodiversity' was coined in the 1980s. According to UNCED (1992), it has evolved only in recent years in the wake of the general biodiversity discourse. Agrobiodiversity is the sub-set of general biodiversity directly developed and managed by humans. Analogous to the term biodiversity, agrobiodiversity encompasses different levels. It refers to the biodiversity of agroecosystems along with species of crops and farm animals, and the genetic variance within populations, varieties and races. Soil organisms, insects, fungi, and wild species from off-farm natural habitats as well as cultural and local knowledge on biodiversity form the basis of the exploitation of biodiversity (Baudron and Giller, 2014). Four principal components of agrobiodiversity exist:

1) genetic resources for food and agriculture;
2) biodiversity that supports ecosystem services of agriculture;
3) abiotic factors, e.g., climate; and
4) socioeconomic and cultural dimensions (Zimmerer, 2014).

Agricultural expansion and intensification led to biodiversity loss in agroecosystems (Tscharntke et al., 2012) and reduction in the types and levels of ecosystem services that people benefit from (Barral et al., 2015). Farmland biodiversity is a ground for provision of ecosystem services needed to sustain agriculture per se and the environment as a whole (Overmars et al., 2014). According to Yao and Li (2010), agrobiodiversity includes all crops and livestock, their wild relatives, and all interacting and supporting species such as pollinators and symbiotic agents, in relation with pests, parasites, predators and competitors. In the current definition, agrobiodiversity refers to a comprehensive concept emphasizing crops and livestock (i.e. those are involved in food production process). The Food and Agriculture Organization (FAO) explains agrobiodiversity as the variety and variability of animals, plants and micro-organisms that are crucial for food and agriculture, and which originate from the interaction between the environment, genetic resources and the management systems and those practices used by people. In particular, it contains two categories:

1) the wild relatives of domesticated species (for example, wild relatives of crop species or species that are genetically usable breeding materials);
2) or breeding individuals of plants and domesticated animals (which in the case of crops, is referred as landraces) (Amend,et al., 2008). This FAO definition seems to be comprehensive and acceptable in many scientific communities.

The status of agrobiodiversity varies in the world. For example, Overmarset al. (2014) revealed that the state of the overall biodiversity in agriculture is better in the southern and eastern parts compared to the western and northern part of the European Union (EU). They adopted a species-oriented methodology enabling spatially explicit indicator for biodiversity quantification on agricultural lands. The provided map demonstrates great variety in the state of the biodiversity of agricultural areas in the EU.

When natural ecosystems are shifting towards agroecosystems, biodiversity is directly modified (via additions and removals of biota) or indirectly modified (via the alteration of biogeochemical cycles, hydrological cycles and species habitats) targeted to increase yield for human benefit. In turn, undergoing changes in biodiversity will change ecosystem functions and processes via changes in species traits (Webb et al., 2010; Baudron and Giller, 2014).

The replacement of abundant species with gene pool poor high-yield plant species resulted in a decline of agrobiodiversity (Wolff, 2004). The decline in biodiversity is also associated with agricultural management practices, such as fertilization, irrigation, machinery-driven weed removal, and pesticide and fungicide applications (Wolff, 2004). Furthermore, new high-performance breeds do not need to adapt to short term or long term environmental changes since all of their needs are attempting to provide supplementary materials. This trend is supported through new breeding programs, focusing on increasing further yield and production power towards top performers. Attempts focus on artificial insemination, multiple ovulation and embryo transferring livestock and genetically homogenous and high performing plant varieties. These efforts are expected to exclude a number of individuals from breeding programs. Consequently, the genetic distance within populations is expected to increase (Wetterich, 2001; Wolff, 2004).

3.1.2. Biodiversity as a necessity in sustainable agriculture

Modern agricultural systems have adverse effects on environmental aspects of production and ecosystem health. Loss of biodiversity due to monoculture is one of these adverse consequences. Maximizing the yield of a limited number of plant and animal species, in the agricultural business inevitably weaken and reduce competitiveness with undesired species (OECD, 2001). It is irrefutable that biodiversity and agriculture are interrelated and could benefit. In contrast to modern agricultural systems, sustainable agriculture enables us to produce food without limiting future generations' ability to do so. Biodiversity is one of the most important elements to manage the systems toward a nature framework (Pretty, 2008). From ecological perspective, biodiversity is the basis of survival of the system and could be considered a vital component of sustainable farming systems.

3.1.3. Services of biodiversity in urban agricultural (UA) systems

Production of crop and livestock products within cities and towns is referred to as urban agriculture (UA) (Zezza and Tasciotti, 2010). This incorporates the local urban socio-economic and ecological system (Lin et al., 2015).

Simplified green spaces and intensively developed ecosystems with low levels of native biodiversity in urban land use can enhance biodiversity and consequently provide functions and services across fragmented habitats (Lin and Fuller, 2013). These functions and services e.g. include cultivating, processing, and distributing functions of food in or around a village, town, or city within the scope of agroforestry, aquaculture, beekeeping, and horticulture. In cities, particular biodiversity services can provide services for storm water runoff, mitigation of air pollution, contribution of carbon storage and sequestration, and delivery of improved water quality (McLain et al., 2012; Lin et al., 2015).

In urban agriculture, biodiversity has increasing adverse effects on some ecosystem functions. For example, particular plants and microorganism are considered weeds and pathogens respectively and potentially harm native ecosystems and interfere with ecosystem service delivery from natural systems (Blitzer et al., 2012; Zhang et al., 2007; Lin et al., 2015).

3.1.4. Pest control by biodiversity in agroecosystems

Agricultural intensification can be defined as an increase in agricultural production per unit of inputs. Intensification is based on the selection of special crops and crop varieties adapted to their spatiotemporal environmental conditions. Thus, the loss of biodiversity has been exacerbated the pest control challenges in agroecosystems (Hill, 1987). Cultural, mechanical, chemical, and biological controls are the most applied options to overcome pests. With the agricultural intensification, use of pest biocontrol methods has diminished (Benbrook, 2001). Instead, chemical treatments and the use of genetically modified organisms have been adopted to control or manage pests (Benbrook, 2001). Thus, natural system control has been shifted to human induced control mechanisms. These changes increased environmental costs, water and groundwater pollution, and higher biodiversity losses in agroecosystems (Bengtsson et al., 2005; Philpott, 2013).

Natural enemies were considered elements to suppress pests or reduce the damage caused by them. Records from around 300 CE show that Chinese farmers used ants and natural enemies in orange groves to control mite populations (Huang and Yang, 1987). Traditional biological control mechanisms were applied to reduce pests, decreased yield, economic loss, and consequently human disasters. In the 1980s, 160 species of predatory arthropods and 16 insectivorous birds were released for pest control in the USA (Letourneau et al., 2009). So far, more than 2000 species have been released worldwide (Philpott, 2013).

Among the modern agricultural systems, organic farming encounters more variety of pests and insects than conventional agroecosystems. Crowder et al. (2010, 2012) showed that organic farming systems may partly lead to increased richness while having significant positive influences on evenness and abundance in comparison to conventional systems. Due to reduced insecticides application or improved habitat biodiversity, the positive influences of organic farming systems can be important on richness and abundance of organisms (Crowder and Jabbour, 2014; Bengtsson et al., 2005; Hole et al., 2005).

Principally, habitat heterogeneity can strongly benefit pest control services (Philpott, 2013). A high degree of habitat heterogeneity in agricultural landscapes can increase the biodiversity of natural enemies in crop fields, and provides stability of resources form natural enemy populations (Altieri, 1999). This heterogeneity could attract natural enemies to agroecosystems. To maximize human benefits of farming systems, identification of species and an integrated consideration of different aspects of communities such as evenness, and richness are required (Crowder and Jabbour, 2014). Crop rotation and integrated crop-animal based systems are two known options to improve and conserve biodiversity and meliorate different ecosystem services. Yet, the relationships between biodiversity and biological control in agroecosystems have not been settled and most of the mechanisms underlying these relationships remain unclear (Crowder and Jabbour, 2014).

3.2. Biodiversity and carbon sequestration

Different factors such as alleviating soil degradation, agricultural practices and desertification with conserving soil organic matter in the surface layer could enhance the soil's capability to sequester carbon (Batjes and Sombroek, 1997). Slowing down the soil degradation process and impeding desertification could lead to annual conservation of over 0.5–1.5 Pg C globally (Dixon et al., 1994). The practices leading to considerable return of soil biomass and soil organic matter are causes of enhanced carbon sequestration in agroecosystems. Thus, all practices that increase diversity at species and genetic level and various time scales, can improve agroecosystems capability to sequester carbon (Hajjar et al., 2008). The positive relationship between biodiversity and carbon stocks has been confirmed with coincidence of variation with biomass value and carbon content.

Terrestrial ecosystems can save about 2100 Gt carbon in living organisms, litter, and soil organic matter globally. This amount is estimated to be three times as much carbon as stored in the atmosphere. For that reason, living organisms play an important role in climate regulation. Carbon storage in ecosystems among other factors depends on the species composition, available soil types, and climate change. Degradation of the entire (or part of) an ecosystem reduces its capability to sequester and store carbon. Thus, if the share of carbon capturing for climate mitigation is considered important, maintaining carbon sources is required at global scale (European Commission, 2009).

3.3. Biodiversity in life cycle assessment (LCA)

Two approaches are available for the evaluation of the effects of agricultural activities on biodiversity. The first approach is indicator-based by landscape heterogeneity and landscape ecological structures, whereas the second shows how biodiversity can be included in LCAs (Jeanneret et al., 2014). LCA is a systematical method to evaluate product or service from environmental aspects (calculating cradle-to-grave environmental impacts). It considers all inputs and outputs involved in the generation of a product or service with respect to the surrounding environmental conditions. The biodiversity concept could be integrated into LCA at global scale, with regard to species richness of a natural reference situation compared to different land use types (Baan et al., 2013). An alternative approach is to consider concepts of ecosystem scarcity, vulnerability, and conditions in order to maintain biodiversity in the specific case of forestry (Michelsen, 2008).

LCA is mainly considered an endpoint category, modeling the loss of species richness through spatial and temporal land use conversion. Real dynamics and complexity of the interactions among species and their habitats have been taken to simplified land-use modeling approaches (Souza et al., 2015). An expert system was developed by Jeanneret et al. (2014) to consider LCA impact categories in agricultural productions. The developed method is valid for grasslands, arable crops and semi-natural habitats of the farming landscape and estimation of the impact of management systems on biodiversity. The use of eleven indicator-species groups provided a differential and comparatively comprehensive assessment of the impacts of the agricultural operations on biodiversity.

3.4. Role of biodiversity in ecological restoration (ER)

Ecological restoration (ER) is considered a major strategy to improve the provision of ecosystem services and reversing biodiversity losses (Bullock et al., 2011). Benayas et al. (2009) were using a meta-

analysis of 89 restoration assessments revealed that ER led to an increase of ecosystem services and biodiversity between 25 and 44%, respectively.

The two strategies are generally implemented through either passive or active restoration. Passive restoration implies the removal of degrading factors, while active restoration involves management actions (Morrison and Lindell, 2011) such as adding desired plant species and improving the soil, which both drive secondary succession. However, passive restoration most frequently implicates secondary succession following dereliction of agricultural land in the areas previously used for crop or livestock farming. ER could be a solution to help reverse global biodiversity losses for those areas, which are facing environmental degradation. Finally, a positive correlation could be established between biodiversity recovery and ER recovery (Balvanera et al., 2006). All components affecting biodiversity such as species distribution, species richness and functional groups could also influence on ER components such as erosion control, reforestation, usage of genetically local native species, revegetation of disturbed areas and reintroduction of native species, which in turn, could link to several indigenous ecosystem processes, leading to enhanced provision of ecosystem services (Bullock et al., 2007).

Species richness is positively linked to the improvement of several ecosystem processes, and related services such as nutrient cycle and biomass production (Balvanera et al., 2006; Bullock et al., 2007). ER of agroecosystems could be advised as an effective way to improve biodiversity in these ecosystems (Barral et al., 2015).

3.5. Land-use influencing biodiversity

Although land use activities have positive effects on biodiversity of a region in many cases, land use might also lead to decreasing species abundance (Henzen, 2008). The interrelationship between land use and biodiversity is vital to apperceive the links between people and surrounding environment (Haines-Young, 2009).

The biodiversity concept along with the overall richness of species, present in a particular area, covers the diversity of genotypes, functional groups, communities, habitats and ecosystems. Consequently, there is a complex relationship between biodiversity and land use (Zeller et al., 2017). These dual relationships are often bilateral and thus identification and justification of cause and effect relationships are difficult. In some places, land use plans or land management activities may be crucial for sustaining specific patterns of biodiversity such as urban forest and urban agriculture (Haines-Young, 2009).

To attain a systemic and systematic conservation plan, assessments of lands impact are required (Desmet and Cowling, 2004; Jost, 2009). These are for example carried out by quantifying and modeling land-use–biodiversity relationships using species diversity (Alkemade et al., 2009; Hackman, 2015). The measurement of biodiversity at landscape scale is performed by assessing species communities in different land-use types. The suitability of land-use systems to conserve the regional species of interest can be used in order to differentiate them. However, the use of different biodiversity measures often leads to ambiguous results among scientists and planners (Hackman, 2015).

Several studies have been published methods for the evaluation of land use effects on biodiversity. For example, Koellner (2001) developed methods for the assessment of vascular plant species in relation to distinct land uses in the region of Central Europe, Denmark, and Malaysia. Hackman (2015) used a power model and a logarithmic model to assess land-use impacts on biodiversity across a landscape and found that the logarithmic model was working better compared to the power model when assessing biodiversity in large areas. Thus, when modeling biodiversity, not only the recognition of the appropriate space and time scale but also the overall concept considered is important.

Land cover, land use, and biodiversity are interdependent. Any land cover/land use change can effect biodiversity and reduce related ecosystem services. Besides climate change, these pressures on the biodiversity and ecosystem services increased policy action management strategies, e.g. through the European Common Agricultural Policy on land (Schroter et al., 2005; Haines-Young, 2009). Biodiversity loss related to land use and its change is related to nature conservation. This driving force especially applies in developing countries, where the demand of natural resources and food are increasing. Therefore it is important to collect data on species richness according to different land use types, because land managements considered a human activity with an incisive impact on biodiversity along with severe influence on other environmental elements (Henzen, 2008). In this regard, Xu (1997) concluded that the changes in agroecosystems are significantly related with the various forces related to changes in technology, economic and biophysical conditions, and modifications in institutional and social settings.

Land sparing and land sharing have been proposed as two incisive models to increase agricultural production along with the alleviation of impacts on biodiversity: Land sparing suffers from several restrictions such as:

a. Yield enhancement may result in reduction of cultivated area.
b. Intensification impacts are more than exclusively the farmed land intensively.
c. Many farmers in developing countries do not have access to knowledge and income to perform intensive farming.

Validity of land sharing is supported by many species dependent on farmlands and habitats managed by humans (Baudron and Giller, 2014).

As for land sparing, land sharing faces two main restrictions:

(1) The impact of land sharing on biodiversity is often equivocal, and
(2) Land sharing generally results in low agricultural yields and may consequently need more space than intensive farming; or it may even hasten land conversion in ecosystems with higher biodiversity value (Baudron and Giller, 2014). Low input farming and little or no agro-chemical application rate also follow land sharing. Obtained yield resulted from such practices is generally less than those attained by intensive farming (Connor, 2008; dePonti and Rijk van Ittersum, 2012; Baudron, and Giller, 2014).

Far from being opposing approaches, land sparing and land sharing should be regarded as different solutions to the same problem (Fischer et al., 2008). Many researchers believe that both approaches are equally important and complement each other in different situations (Cunningham et al., 2013; Baudron, and Giller, 2014).

3.6. Biodiversity for food security and health

Food security is generally referred to the availability and accessibility of food to society. The World Bank defines this phrase as the access of food to all people for an active and healthy life at all times (World Bank, 1986; Maxwell and Wiebe, 1999). The most commonly accepted and used definition for it has been coined at the World Food Summit; food security exists when all people, at all times, have physical and economic access to meet their dietary needs and food preferences for a healthy and active life (Pinstrup-Andersen 2009; Sunderland, 2011).

Nutrient deficiency is constraint by a large group of the world population, especially those living in South Asia and Sub-Saharan Africa. This deficiency occurs in spite of receiving sufficient calories, but insufficient intake of vitamins and minerals. The positive role of consumption of fruit and vegetables has been widely accepted to reduce nutrient deficiency. Cereals, non-cereal grains, pulses, roots and tuber crops, fruit, various edible seeds, and vegetables are high potential crops to provide food security at local and regional levels (Chadha et al., 2007). Moreover, some crops with high nutritive value are

gradually disappearing and are being replaced by high-yielding crops (Adoukonou-Sagbadja et al., 2006; Kahane, et al., 2015). By 2050, agriculture should provide food for almost 9 billion people (Kahane et al., 2015). This requires an increase about 60 percent of global food production. The World Health Organization (WHO) (2008) reported that over 1.62 billion people (including 600 million children) are suffering from anemia, along with serious deficiencies in essential minerals and micronutrients in over a half of them.

Food production is highly dependent on biodiversity and services provided by ecosystems. Although the amount of food supplied by current agricultural activities is sufficient at global scale, the extent of practices undermines the capacity of agroecosystems to preserve biodiversity. However, the interdependence of biodiversity and agriculture, and their mutual role to maintain one another have been highlighted in literature (e.g. Chappell and La Valle, 2011). Land conversion and biodiversity have often been considered as two distinct subjects in agriculture. In order to provide forth-coming population with food security, innovative and feasible ways should be sought to integrate biodiversity conservation and food production (Sunderland, 2011). Maintaining diversity within agroecosystems is not a novel approach, but being performed by many smallholders in many different ways throughout the world is unique. The nutritional and livelihood benefits of diverse production systems are one way to attain food security. Such systems are also more resilient to climate-induced events or other disasters (Kahane et al., 2015). With respect to challenges of food security, richer biodiversity within agricultural systems is increasingly recognized as an important element to contribute to sustainable development (FAO, 2011).

3.7. Effects of climate change on biodiversity and species response

Environmental conditions play a crucial role to explain the function and distribution of plants in space and time. Climate change is a change in the statistical distribution of weather patterns when that change lasts for an extended period of time. Changes in long-term environmental conditions lead to considerable impacts on plant diversity patterns (Sahney et al., 2010). Changing climatic variables like elevating CO_2 concentrations, heat stress, longer drought periods and heavy rainfall events impact functions and the distribution of plants; moreover, changes in the pattern of 'extreme' weather events can collectively affect these function and distributions (Watson et al., 2012).

Climate change is able to reduce genetic diversity due to directional selection and rapid migration, which could in turn affect ecosystem functioning and resilience (Botkinet al., 2007). Species can respond to climate change challenges by shifting their climatic niche along three non-exclusive axes: space (e.g. range), time (e.g. phenology), and themselves (e.g. physiology). The response of some species to climate change may constitute an indirect impact on the species that depend on them (Bellard et al., 2012). Climate change has led to phenological shifts in flowering plants and insect pollinators, causing mismatches between plant and pollinator populations that lead to the extinctions of both the plant and the pollinator with expected consequences on the structure of plant–pollinator networks (Kierset al., 2010). At a higher level of biodiversity, the climate can induce changes in vegetation communities and affect biome integrity. Because of climate changes, species may no longer be adapted to the set of environmental conditions in a given region and could fall outside its climatic niche (Bellard et al., 2012).

Changing the distribution, phenology and abundance of species lead to inevitable changes in the relative abundance of species and related interactions. These changes are expected to affect the structural, process-related and functional aspects of ecosystems (Walther et al., 2002). Species that may no longer be adapted to climate change may expel from their climatic niche. To protect species as individuals, populations, or species, they must be equipped with adaptive responses in different ways (Bellard et al., 2012).

Climate change effects on some agricultural management. For example, food provision for the people in each given region with poor biodiversity resources is one of major challenges in modern agroecosystems. What is the priority action needed? The response to this question will help society to manage the implementation of existing plans and developing upcoming plans (Booth, 2012). Walker and Schulze (2008) suggested that long-term outlooks in regard to ecological integrity and human well-being need to be applied to practices and policies for sustainability of both commercial and small agroecosystems.

Biodiversity could be indirectly affected by climate change resulting from clearing land for farming. For example, the share of deforestation in respect to global CO_2 emissions is about 12%. Unfortunately, loss of carbon is followed by loss of the habitats typically with rich diversity and endemism (West et al., 2013). Liu et al. (2013) estimated biomass, soil quantity and ecosystem organic carbon stocks in four vegetation types typical of Karst ecosystems in south western China, included shrub grasslands (SG), thorn shrubbery (TS), forest – shrub transition (FS) and secondary forest (F). The results showed that organic carbon storage of F is higher than the other mentioned ecosystems.

Based on the prediction proposed by the Intergovernmental (IPCC, 2014) for 2100, and assuming that the current trends in burning fossil fuels will continue as it is, earth surface temperature will increase about 1.4–5.8 °C. It is impossible to predict how and which species and ecosystem will be affected by global warming. It is predicted that by 2050 at least one quarter of all the species on land will become extinct as a consequence of the extreme warming *per se*. This in turn will results in habitats life degradation and cause serious threats. This is especially the case for those species living in temperature sensitive ecosystems (IPCC, 2014).

3.8. Genetic erosion and value of plant genetic resources

The loss of genetic diversity is known as genetic erosion, which is commonly referred to as the reduction in the quantities of specimens of a species (Wolff, 2004). For agricultural crops, however, genetic erosion is not limited to the reduction in the number of plants of a species or in the geographic niche of a given species. The loss of genetic variation among the plants, or specifically the loss of some of the various forms of genes are the main source of the variation in appearance and in the life cycles of plants (Friis-Hansen, 1999). The term genetic erosion is sometimes used in a narrow sense such as for the loss of alleles or genes, as well as more broadly, referring to the loss of varieties or even species (Schmidt and Wei, 2006).

Nowadays, we are dealing with two important concerns in respect to biodiversity in agroecosystems. In addition to replacement of diverse landraces with few or one modern variety, the loss of indigenous knowledge by farmers to manage their own genetic resources is also considerable (Friis-Hansen, 1999). Directing to less genetically diverse populations leads to more pathogen susceptible ecosystems and other environmental limiting and reducing factors. The varieties involved in modern agricultural systems may be less competitive than invasive plants. Overall, genetic erosion can have cascading effects throughout the ecosystem (Sunderland, 2011).

In the process of determining the value of genetic resources (which are valued by their benefits), both the conservation of particular genes or genotypes, and the conservation of biodiversity should be taken into account. Their benefits include resistance to biotic and abiotic stressors such as pests, diseases, drought, salinity, and plant stature. Additionally they positively influence productivity and quality factors such as higher oil or protein content besides culinary and cultural importance. Based on Schmidt and Wei (2006), global environmental change and more intensified agroecosystems lead to genetic erosion, especially in Vavilov centers.

The FAO (2010) estimates that about 75% of the genetic diversity of agricultural crops has been degraded during the last century. A US

survey carried out by the Rural Advancement Fund International (RAFI) found that in 75 crop species, 97% of the varieties listed in the old United States Department of Agriculture catalogues are extinct (Fowler and Mooney, 1990). Europe is also vulnerable to loss of biodiversity. About 90% of the historical biodiversity of crops in Germany and 75% of crop varieties in Southern Italy have been lost (Hammer et al., 2002). Another example referred to rice crop in Sri Lanka, where 75% of grown rice varieties are descended from one maternal parent, along with 62% in Bangladesh, and 74% in Indonesia (Amend et al., 2008).

The identity of about 250,000 out of 500,000 species of higher plants in the world have been recognized or designated. Approximately 30,000 of these identified species are edible and approx. 7000 have historically been used as crops or gathered by humans for food. Today, only 30 crops have a 95% share of the world's calorie and protein demands. On one hand, wheat, rice and maize alone provide more than half the global plant derived energy intake (FAO, 1991, 1996).

On the other hand, seven crops (sorghum, millet, potatoes, sweet potatoes, soybeans, sugar cane and sugar beet) provide half of the energy intake at global scale. In spite of the fact that the number of plant species, which provide the world's energy and protein, is limited, the biodiversity within such species is considerable; e.g. more than 100,000 distinct varieties of rice (Friis-Hansen, 1999; Ezcurra et al., 2001; Schmidt and Wei, 2006). Gao (2003) reports that increase in Chinese population and particularly the rapid growth of market economy since the 1980s caused turning the localities of wild rice into cultivated rice fields, fish ponds, residences, factories, and highways. Therefore, with the drastic change in habitats, the existence of wild rice has been seriously threatened, with most of the populations having disappeared or being endangered.

Biodiversity, both in terms of growing a number of different crops and different varieties of each crop, plays a crucial role in the maintenance of household food security, the major production goal of poor farmers' resource. Such crop diversity allows farmers to adapt their cropping systems to local ecological micro-niches in their fields and to satisfy household food preferences and also provides protection against pathogens. Also, the extent of genetic variation determines how well a population or species can adapt to environmental challenges such as new crop pests, diseases and drought, among others (Simmonds, 1991a,b).

Also, genetic erosion could beacon sequence of global environmental change and more intensified modes of crop production (Schmidt and Wei, 2006). Plant genetic resources can be improved in many ways such as: gene banks for plants and animals, seed banks, field gene banks, sperm banks, protected regions, global germplasm reserves, rare breeds centers, zoos and modern breeding technology, and reintroduction 'back into the wild' programs.

3.9. Biodiversity measurement methods

Biodiversity is a key topic in ecological studies. A main drawback in biodiversity evaluation is that different indicators may lead to different orderings among communities according to their biodiversity. Biodiversity can be measured by many indices such as species richness, evenness, taxonomic indices, Margalef's index, Simpson's index, Shannon-Wiener index etc. In practice, species richness is often used due to its simplicity. Intuitively, however, the applicability of species richness for quantifying species' response to environmental changes is questionable because it is sensitive only to events that cause extreme changes in species abundance distributions. In conclusion, the measurement of ecological differences in communities using solely species richness has been described as ecologically unrealistic (Hackman, 2015).

Many recent studies have proposed new methods and software for dealing with biodiversity assessment. For example, Di Battista et al. (2017) proposed the R package BioFTF, which is a tool for statistical biodiversity assessment in the functional data analysis framework. This tool is a scalar measure that reflects the information provided by the biodiversity profile and allows for ordering communities with different richness. In another study, Cardoso et al. (2015) developed a new tool (BAT – Biodiversity Assessment Tool), i.e. an R package for the measurement and the estimation of alpha and beta biodiversity in their multiple facets (taxon, phylogenetic and functional). This tool performs many analyses, based on either species identities or trees, depicting species relationships. Using this approach, functions include building randomized accumulation curves for alpha and beta diversity, alpha diversity estimation from incomplete samples and the partitioning of beta diversity in its replacement and richness difference components.

The analysis of interactions between biodiversity and environmental characteristics are crucial. Di Battista et al. (2016) applied functional data analysis to the beta diversity profile for the analysis of the relationship between qualitative variables and a functional response. Since the diversity profile is a function of the relative abundance vector in a fixed domain, this method could be helpful to monitor or to identify areas of high environmental risk. Moreover, the proposed approach allows overcoming the limitations of the classical biodiversity indices.

Ricotta et al. (2003) described the computer program "LaDy" (Landscape Diversity Software), for computing Rényi's local landscape diversity profile on raster land cover maps. LaDy software is based on the use of Merchant's adaptive geographic window, which is designed to operate on a neighborhood of patches instead of a fixed rectangular neighborhood of pixels.

Entropart is an R package designed to estimate diversity based on HCDT entropy (Tsallis entropy) or similarity-based entropy developed by Marcon and Hérault (2015). It allows calculating species-neutral, phylogenetic and functional entropy and diversity, partitioning them and correcting them for estimation bias. Ricotta and Avena (2003) offered a simple analytical relation between Pielou's evenness and landscape dominance within the broader context of Hill's parametric diversity family. Within this context, they recommend the use of Hill's diversity number evenness to overcome the shortcomings both of Pielou's evenness and the landscape dominance index.

The agrobiodiversity index is a consistent, long-term monitoring tool to measure and manage biodiversity across four dimensions: diets, production, seed systems, and conservation (Ann Tutwiler, 2016). Blanco et al. (2015) proposes a novel index to assess agrobiodiversity in systems that mix species, varieties, life forms, and uses. The new index was compared with the Shannon and Pielou indexes, which were proved accurate for assessing and monitoring agrobiodiversity at the species and varietal levels. Shannon and Pielou concluded that the index is a useful tool for agrobiodiversity monitoring in agricultural systems undergoing changes in practices and for achieving a better understanding of their biocultural resilience.

4. Discussion

According to the present literature review, biodiversity services are critical in modern agroecosystems. Increasing biodiversity can favorably affect some ecosystem functions. But, current agricultural expansion and intensification led to biodiversity loss in agroecosystems. In this regard, when natural ecosystems are shifting to modern agroecosystems, biodiversity can be directly or indirectly modified to increase benefits to agroecosystems. For example, habitat heterogeneity could lead to attract natural enemies to agroecosystems. To maximize benefits of heterogeneity systems, identification of species and an integrated consideration of different aspects of communities such as evenness, and richness are essential components.

Many key ecosystem services and roles are provided by biodiversity (Tables 1 and 2). These services play a fundamental role in human food security and health. Promoting the healthy functioning of ecosystems ensures the resilience of agriculture as it intensifies to meet growing demands for food production. Climate change and other stresses have

the potential to make major impacts on some functions, such as pollination and pest regulation services. Learning to strengthen the ecosystem linkages that promote resilience and to mitigate the forces that impede the ability of agroecosystems to deliver goods and services remains an important challenge. Agroecosystems managers can build upon, enhance, and manage the essential ecosystem services provided by biodiversity in order to work towards sustainable agricultural production. This can be achieved by good farming practices which follow ecosystem-based approaches designed to improve sustainability of production systems (FAO, 2011).

At all times, biodiversity directly provides societal needs to resources and food security. As a result, biodiversity is an irreplaceable good for human societies and natural ecosystems. It contributes to ecological restoration, pest control, higher carbon sequestration, lower erosion risk, and higher production. Nowadays, scientists believe that food production is highly dependent on biodiversity and the services provided by ecosystems. In addition, genetic erosion and land use change can effect on biodiversity. Based on available scientific knowledge, there is a complex relationship between biodiversity and land use (Haines-Young, 2009). While land use activity could have positive effects biodiversity, in most cases, it leads to species degradation. Many researchers suggested that the LCA technique could be used to assess the effects of human activities such as land use on biodiversity (Souza et al., 2015). LCA principally introduces biodiversity as an endpoint category modeled as a loss in species richness due to the conversion and management of land in time and space.

Recent studies have revealed a global decline in biodiversity. Loss of biodiversity due to monoculture is one of adverse effects of modern agricultural systems. Some activities such as agriculture and forestry are one of the most important ways to increase the biodiversity in urban land uses. It seems that coming green spaces to typically highly simplified, intensively developed ecosystems with low levels of native biodiversity in these land uses (Lin and Fuller, 2013). These urban systems could enhance biodiversity and provide some ecological function and services. Also, biodiversity is the basis of survival of the natural systems and could be considered a vital component of sustainable farming systems.

Considering the current state of biodiversity in the world, the need to reduce the current rate of resource degradation is increasing. Today, we have to use the ability of biodiversity to support modern agroecosystems by providing numerous services such as food security, carbon sequestration, pest control, and its effect on climate change and genetic erosion reduction rather than focusing on agrochemical substances such as Glyphosat presently under debate in the member states of European Union.

To protect biodiversity in agroecosystems, a policy consonance and strategic support to ecosystems should be considered. This review suggests that the challenges of food security, climate change, genetic erosion, pest control, carbon restoration and biodiversity loss in agroecosystems need a coherent global policy approach. For example, major challenges in agronomy include the need to shift to species or varieties better adapted to particular components of climate change or to rethink strategies to control invasive and pest outbreaks, finding solutions in the increasing competition for water between the natural and the agricultural ecosystems, improving infrastructures and adapting cropping systems to meet future demands of a growing population living on poorer biodiversity resources (Bellard et al., 2012).

5. Conclusions and outlook

This paper aimed to introduce biodiversity roles and services in modern agroecosystems in response to some of the societal and environmental challenges from local to global scale, the ability of biodiversity to support such ecosystems, and the agenda for future research. The conservation, management, and sustainable use of ecosystem services require specific attention. With respect to challenges of food security, richer biodiversity within agroecosystems should be increasingly recognized as an important element to contribute to sustainable development.

Some studies have shown, how biodiversity can actually influence on the loss of genetic diversity (genetic erosion). The extent of genetic variation determines the state of adaptation of a population or species to environmental challenges such as new crop pests, diseases and drought. Biodiversity helps farmers matching their cropping systems to local ecological micro-niches in order to provide the household food requirements and protecting them against pests. Considering genetics erosion as one of the important challenges of the agroecosystems, this review suggests that advanced studies are needed in this subject. Also, recent evidence reveal that for extending biological controls strategies in agroecosystems, the relationship between agroecosystems intensification, biodiversity and pests control needs to be supported. It should be considered that the loss of diversity of natural enemies in agroecosystems increased water and groundwater pollution and environmental costs.

Geographic information about biodiversity is helpful and crucial to understand the services that are provided by nature and their potential changes; however, our knowledge in these respects is unreliable and often insufficient. This paper suggests that further studies are needed in this subject in regions with reduced biodiversity resources.

To protect biodiversity in agroecosystems, a policy consonance and strategic support to ecosystems need to be framed. This review suggests that the challenges of food security, climate change, genetic erosion, pest control, carbon restoration and biodiversity loss in agroecosystems need a coherent global policy approach. For example, major challenges in agroecosystems include the need to shift to varieties better adapted to particular components of climate change or to rethink strategies to control invasive and pest outbreaks, finding solutions in the increasing competition for water between the natural and the agricultural ecosystems. This paper suggests that more studies are needed in order to improve infrastructures and adapting agroecosystems to meet future demands of a growing population living on poorer biodiversity resources.

A number of points need to be highlighted. First, other advanced studies need about ecological restoration of agroecosystems that it can be recommended as a way to increase biodiversity in agricultural ecosystems. Second, biodiversity can be integrated into LCA on a global scale. Third, map of life attempts to provide best-possible species range information and species lists for different geographic areas. The map of life aims to support effective and biodiversity education, monitoring, research and decision-making by combining a wide range of knowledge about species distributions and their dynamics. Thus, it can be considered as attractive studies in future. Fourth, the relationships between biodiversity and biological control in agroecosystems have not been settled completely, therefore, supplementary research is recommended in this regard. As a final point, it could be concluded that effective improvement and conservation biodiversity in agroecosystems is urgently required. Moreover, policy coordination and strategic support to agricultural systems will be considereundeniable necessities in future.

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